ROTATION OF EUROPA: CONSTRAINTS FROM TERMINATOR POSITIONS. Gregory V. Hoppa, Richard Greenberg, Paul Geissler, J. Plassmann, B. R. Tufts, Lunar and Planetary Lab, University of Arizona, Tucson, Arizona, and the Galileo Imaging Team.

Tidal torques on Europa due to Jupiter would tend to drive Europa's rotation to a rate slightly faster than synchronous, unless synchroneity is maintained by a permanent asymmetry in Europa's mass distribution [1]. Moreover, global fracture patterns on Europa's surface, as well as the complex fine-scale tectonics revealed by Galileo high-resolution imagery, may be evidence of stress due to non-synchronous rotation (e.g., [2]). A direct measurement of Europa's rotation rate has been made by measuring the positions of surface features relative to the terminator in a Galileo image, and comparing the results with similar measurements of the positions of the same features relative to the terminator in a Voyager 2 image taken seventeen years earlier.

The Galileo image was taken at 1.6 km/pixel during the spacecraft's first orbit. A projected version (sinusoidal, equal area, with north up, and east to the right) is shown in Fig. 1, showing latitudes from 8° to 30°, with selected reference features (marked) spanning longitudes 157° to 172° (W of prime meridian near sub-Jupiter). At the time this image was made, the sub-solar point (90° from the nominal terminator) was at –1.39° lat, 245.88° long. The apparent terminator may be shifted from the nominal position due to shadowing and subjective appearance. In order to have a consistent, objective means of defining the apparent terminator, we select (for each latitude) the longitude at which straight-line fits to the reflectance profile on both sides intersect. This determination was made over the full range of latitudes in Fig. 1 generating the wiggly vertical profile at the right. The straighter curve through these points is a best fit line parallel to the nominal terminator. The 25 reference features indicated in Fig. 1 were measured relative to that line. An identical procedure was followed for the Voyager image (Fig. 2).

For synchronous rotation after the Voyager epoch, features in the Galileo image (Fig. 1) would be expected to be 14.13° closer to the terminator than in Fig. 2. In fact, on average, the shift is found to be only 13.0°, suggesting slower-than-synchronous rotation by about 1° in 17 yr. Sources of random errors are (a) uncertainty in apparent terminator longitude (sigma = 0.4° for Voyager and 0.3° for Galileo) and (b) inconsistencies in measuring reference feature positions (±0.1°). The combined error range is ±0.5°, only half of the apparent shift due to non-synchronous rotation (1.1°).

Topography plays a significant role in governing the position of the apparent terminator. Even 100-m high features (like Europa ridges [3]) cast shadows 20 km (0.7°) long. The terminator is shifted toward the sun by that amount in terrain characterized by such topography. If the character of the topography is different at the location of the terminator in the two images, a systematic error may be introduced. Also, if the albedo varies with location, the apparent terminator may shift (toward the day side for lower albedo given our definition of apparent terminator).

An example of a systematic shift with change in geologic province may be the shift in apparent terminator longitude by ~1° at latitude 24° in Fig. 2, which corresponds to a transition from mottled terrain to bright plains [4]. Because the terminator in the Galileo image (Fig. 1) is entirely in bright plains, it might be appropriate to limit the comparison to the bright-plains portion of the Voyager image (N of 24°), in which case we would obtain synchronous rotation (±0.3°).

Other potential sources of systematic error are: (a) local topographic features, e.g., the nearly N-S oriented triple-band ridge near the terminator in the Galileo image may shift the apparent position of the terminator, but our objective method of determination is relatively insensitive to local topography; (b) the broad regional figure of the body, e.g., an effective radius of curvature 2% different from Europa's mean radius could shift the terminator difference by 0.3°; and (c) changes in apparent position of terminator due to differences in observational phase angle.

An independent determination of rotation was attempted by considering the position of the feature Cilix, which appears close to the terminator on a Galileo C3-orbit image. Comparing this feature in both Voyager and Galileo images, again using the terminator as described above, we found a faster than synchronous shift of 0.1° ±0.5°. However, this measurement suffers from the fact that the Galileo terminator topography is dominated by Cilix (a high relief feature [5]), so only a few rows of data allow undisturbed measurement. Even in those rows, the anomalously low albedo may shift the apparent terminator artificially westward in the Galileo image (similarly to the eastward shift of the bright plains terminator in Fig. 2), yielding artificially fast apparent rotation.

Any prograde rotation relative to synchronous (such as that predicted by [1]) is less than a few tenths of a degree in 17 yr (a complete rotation in 10^4 yr). Any suggestion of possible slower-than-synchronous rotation may be due to systematic albedo or topographic effects as described above. Or, if real, such slow rotation might be due to unanticipated complex geophysical responses in Europa to the tidal potential of Jupiter. Also, the torque due to Io at each Europan apojove may be comparable to the net torque due to Jupiter and would tend to produce slower than synchronous rotation of Europa.

References: [1] Greenberg R. and S. J. Weidenschilling (1984) *Icarus, 58,* 186. [2] Geissler et al. (1997) *LPS XXVIII,* this volume. [3] Smith B. A. et al. (1979) *Science, 206,* 927. [4] Lucchitta B. et al. (1982) in *Satellites of Jupiter*, 521–555, Univ. of Arizona, Tucson. [5] Belton M. J. S. et al. (1996) *Science, 274,* 377.

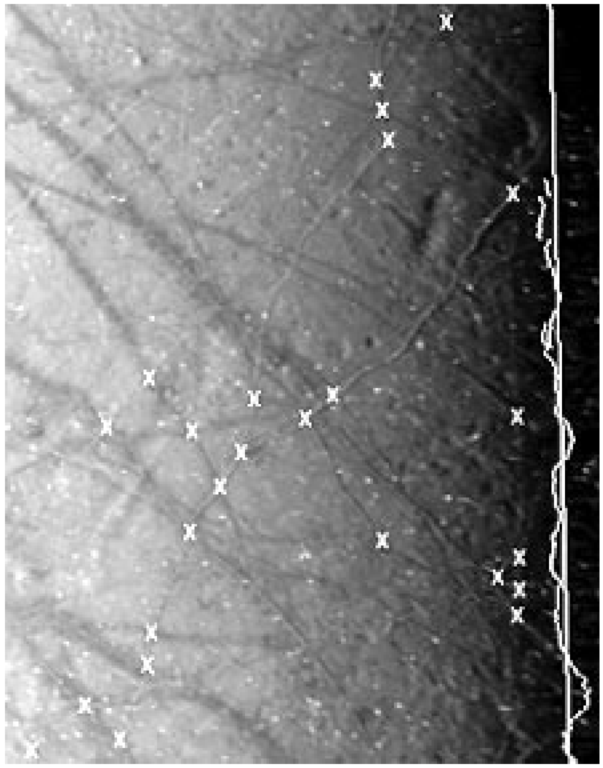

Fig. 1. Galileo.

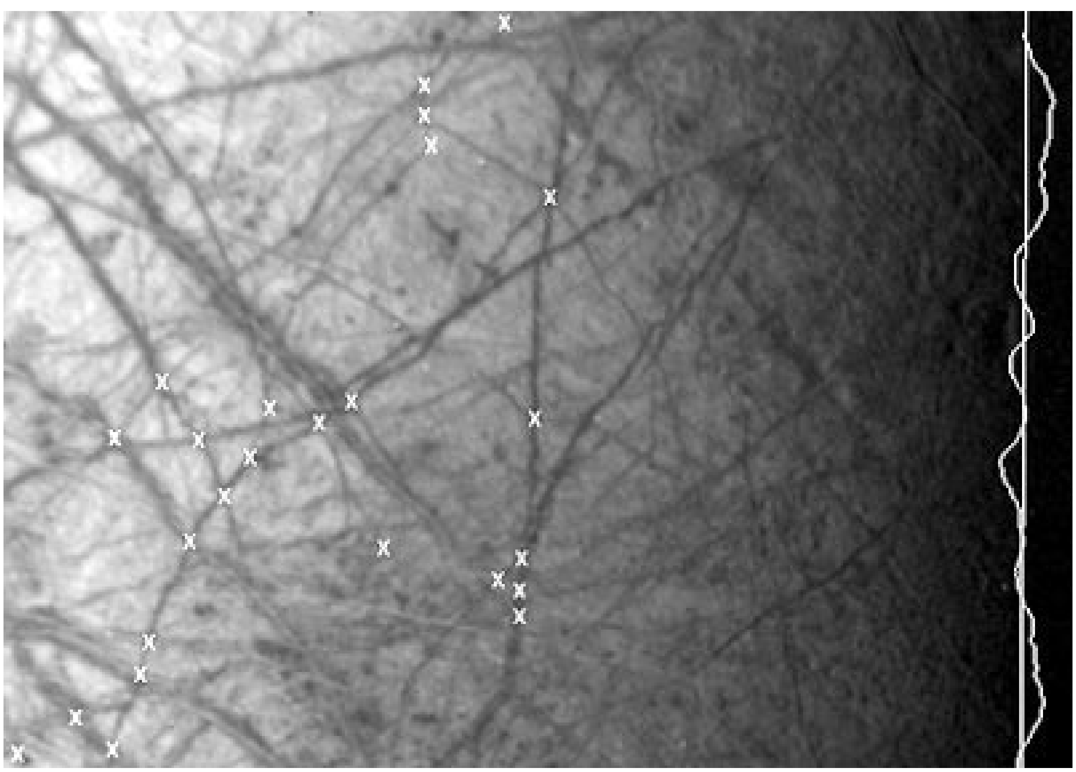

Fig 2. Voyager 2.